Lessons Learned

From Natural Gas STAR Partners

CONVERT GAS PNEUMATIC CONTROLS TO INSTRUMENT AIR

Executive Summary

Pneumatic instrument systems powered by high-pressure natural gas are often used across the natural gas and petroleum industries for process control. Typical process control applications include pressure, temperature, liquid level, and flow rate regulation. The constant bleed of natural gas from these controllers is collectively one of the largest sources of methane emissions in the natural gas industry, estimated at approximately 24 billion cubic feet (Bcf) per year in the production sector, 16 Bcf from processing and 14 Bcf per year in the transmission sector.

Companies can achieve significant cost savings and methane emission reductions by converting natural gas-powered pneumatic control systems to compressed instrument air systems. Instrument air systems substitute compressed air for the pressurized natural gas, eliminating methane emissions and providing additional safety benefits. Cost effective applications, however, are limited to those field sites with available electrical power, either from a utility or self-generated.

Natural Gas STAR partners have reported savings of up to 70,000 thousand cubic feet (Mcf) per year per facility by replacing natural gas-powered pneumatic systems with instrument air systems, representing annual savings of up to $210,000 per facility. Partners have found that most investments to convert pneumatic systems pay for themselves in just over one year. Individual savings will vary depending on the design, condition and specific operating conditions of the controllers.

Method for Reducing Gas Loss[1]	Average Volume of Gas Saved (Mcf/Year)	Average Value of Gas Saved ($/Year)[1]	Average Cost of Implementation ($/Year)[2]	Average Payback (years)
Replace Gas with Air in Pneumatic Systems (per facility)	20,000	60,000	50,000	< 1

[1]Assumed value of gas is $3.00/Mcf.
[2]Cost of installing compressor, dryer and other accessories, and annual electricity requirements.

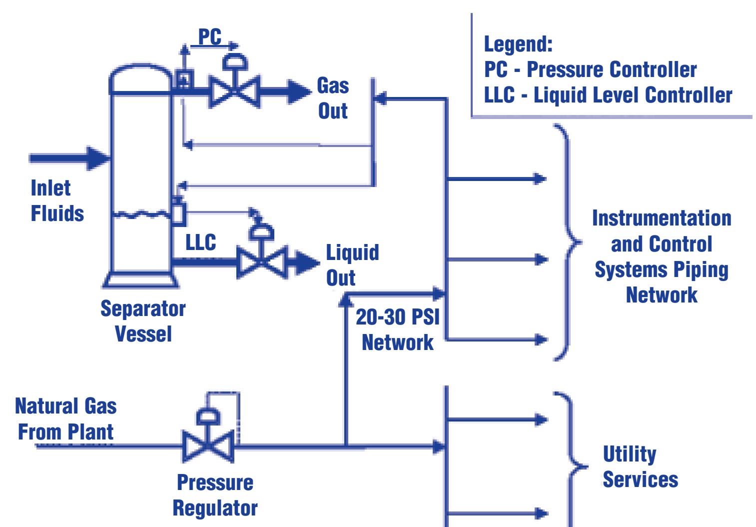
This is one of a series of Lessons Learned Summaries developed by EPA in cooperation with the natural gas industry on superior applications of Natural Gas STAR Program Best Management Practices (BMPs) and Partner Reported Opportunities (PROs).

Technology Background

The natural gas industry uses a variety of process control devices to operate valves that regulate pressure, flow, temperature, and liquid levels. Most instrumentation and control equipment falls into one of three categories: (1) pneumatic; (2) electrical; or (3) mechanical. In the vast majority of applications, the natural gas industry uses pneumatic devices, which make use of readily available high-pressure natural gas to provide the required energy and control signals. Pneumatic instrument systems powered by high-pressure natural gas are used throughout the natural gas industry. In the production sector, an estimated 250,000 pneumatic devices control and monitor gas and liquid flows and levels in dehydrators and separators, temperature in dehydrator regenerators, and pressure in flash tanks. Most processing plants already use instrument air, but some use gas pneumatics, and including the gathering/booster stations that feed these processing plants, there are about 13,000 gas pneumatic devices in this sector. In the transmission sector, an estimated 90,000 to 130,000 pneumatic devices actuate isolation valves and regulate gas flow and pressure at compressor stations, pipelines, and storage facilities. Pneumatic devices also are found on meter runs at distribution company gate stations and distribution grids where they regulate flow and pressure.

Exhibit 1 depicts a pneumatic control system powered by natural gas. The pneumatic control system consists of the process control instruments and valves that are operated by natural gas regulated at approximately 20-30 pounds per square inch (psi), and a network of distribution tubing to supply all of the control instruments. Natural gas is also used for a few "utility services," such as small pneumatic pumps, compressor motor starters, and isolation shutoff valves. Exhibit 2 shows a simplified diagram of a pneumatic control loop. A process condition, such as liquid level in a separator vessel, is monitored by a float that is mechanically linked to the liquid level controller

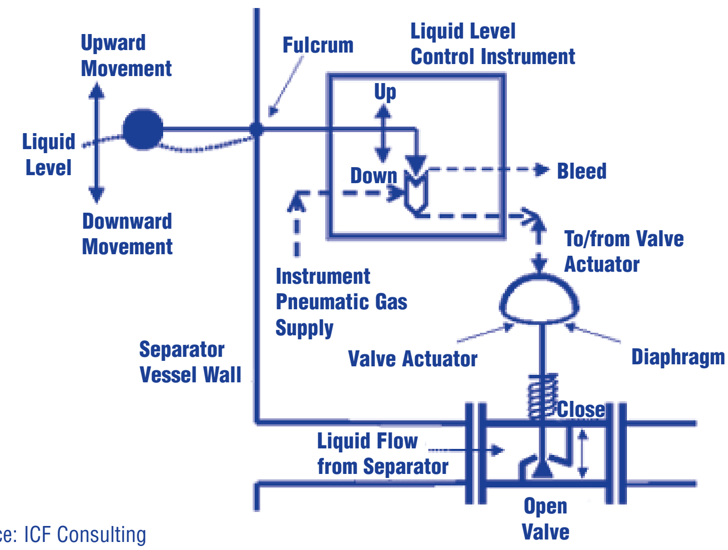
Exhibit 1: Natural Gas Pneumatic Control System



Source: ICF Consulting

outside the vessel. A rise or fall in liquid level moves the float upward or downward, which is translated to small needle valves inside the controller. Pneumatic supply gas is either directed to the valve actuator by the needle valve pinching off an orifice, or gas pressure is bled off the valve actuator. Increasing gas pressure on the valve actuator pushes down a diaphragm connected by a rod to the valve plug, causing the plug to open and increasing the flow of liquid draining out of the separator vessel. Gas pressure relieved from the valve actuator allows a spring to push the valve plug closed.

Exhibit 2: Signal and Actuation Schematics



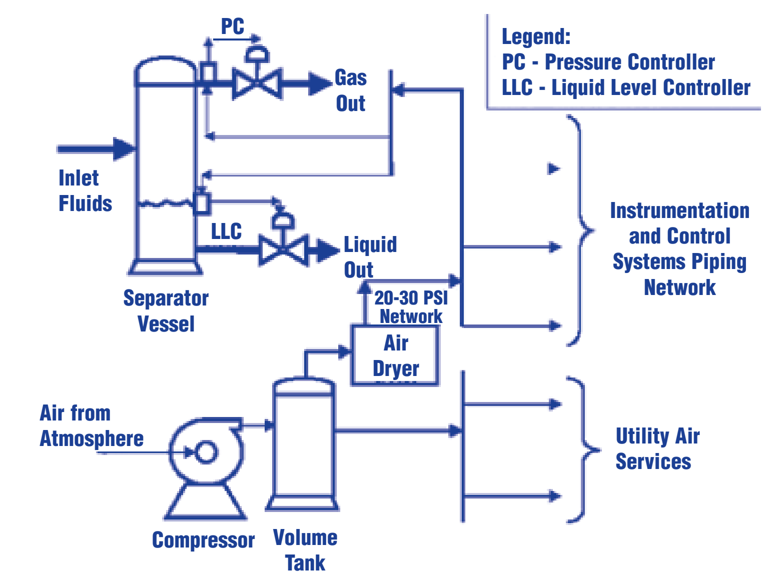
Source: ICF Consulting

As part of normal operation, natural gas powered pneumatic devices release or bleed gas to the atmosphere and, consequently, are a major source of methane emissions from the natural gas industry. Pneumatic control systems emit methane from tube joints, controls, and any number of points within the distribution tubing network. The actual bleed rate or emissions level largely depends on the design of the device. In general, controllers of similar design have similar steady-state bleed rates regardless of brand name. The methane emission rate will also vary with the pneumatic gas supply pressure, actuation frequency, and age or condition of the equipment.

Many partners have found that it is economic to substitute compressed air for natural gas in pneumatic systems. The use of instrument air eliminates methane emissions and leads to increased gas sales. In addition, by eliminating the use of a flammable substance, operational safety is significantly increased. The primary costs associated with conversion to instrument air systems are initial capital expenditures for installing compressors and related equipment and operating costs for electrical energy to power the compressor motor. Existing pneumatic gas supply piping, control instruments, and valve actuators of the gas pneumatic system can be reused in an instrument air system.

A compressed instrument air system is shown in Exhibit 3. In these systems, atmospheric air is compressed, stored in a volume tank, filtered and dried for instrument use. Air used for utility services (e.g. small pneumatic pumps, gas compressor motor starters, pneumatic tools, sand blasting) does not need to be dried. All other parts of a gas pneumatic system will work the same way with air as they do with gas.

Exhibit 3: Compressed Instrument Air System



Source: ICF Consulting

The major components of an instrument air conversion project include the compressor, power source, dehydrator, and volume tank. The following are descriptions of each of these components along with important installation considerations.

★ **Compressor.** Compressors used for instrument air delivery are available in various types and sizes, from rotary screw (centrifugal) compressors to positive displacement (reciprocating piston) types. The size of the compressor depends on the size of the facility, the number of control devices operated by the system, and the typical bleed rates of these devices. The compressor is usually driven by an electric motor that turns on and off, depending on the pressure in the volume tank. For reliability, a full spare compressor is normally installed.

★ **Power Source.** A critical component of the instrument air control system is the power source required to operate the compressor. Because high-pressure natural gas is abundant and readily available, gas pneumatic systems can run uninterrupted on a 24-hour, 7-day per week schedule. The reliability of an instrument air system, however, depends on the reliability of the compressor and electric power supply. Most large natural gas plants have either an existing electric power supply or have their own power generation system. For smaller facilities and remote locations, however, a reliable source of electric power can be difficult to assure. In some instances, solar-powered battery-operated air compressors can be cost effective for remote locations, which reduces both methane emissions and energy consumption. Small natural gas powered fuel cells are also being developed.

- ★ **Dehydrators.** Dehydrators, or air dryers, are an integral part of the instrument air compressor system. Water vapor present in atmospheric air condenses when the air is pressurized and cooled, and can cause a number of problems to these systems, including corrosion of the instrument parts and blockage of instrument air piping and controller orifices. For smaller systems, membrane dryers have become economic. These are molecular filters that allow oxygen and nitrogen molecules to pass through the membrane, and hold back water molecules. They are very reliable, with no moving parts, and the filter element can be easily replaced. For larger applications, desiccant (alumina) dryers are more cost effective.
- ★ **Volume Tank.** The volume tank holds enough air to allow the pneumatic control system to have an uninterrupted supply of high pressure air without having to run the air compressor continuously. The volume tank allows a large withdrawal of compressed air for a short time, such as for a motor starter, pneumatic pump, or pneumatic tools, without affecting the process control functions.

Economic and Environmental Benefits

Reducing methane emissions from pneumatic devices by converting to instrument air control and instrumentation systems can yield significant economic and environmental benefits for natural gas companies including:

- ★ **Financial Return From Reducing Gas Emission Losses.** Assuming a natural gas price of $3.00 per Mcf, savings from reduced emissions can be estimated at $360 per year per device or $210,000 or more per year per facility. In many cases, the cost of converting to instrument air can be recovered in less than a year.
- ★ **Increased Life of Control Devices and Improved Operational Efficiency.** Natural gas used in pneumatic control devices and instruments often contains corrosive gases (such as carbon dioxide and hydrogen sulfide) that can reduce the effective operating life of these devices. In addition, natural gas often produces by-products of iron oxidation, which can plug small orifices in the equipment resulting in operational inefficiencies or hazards. When instrument air is used, and properly filtered and dried, system degradation is reduced and operating life is extended.
- ★ **Avoided Use Of Flammable Natural Gas.** Using compressed air as an alternative to natural gas eliminates the use of a flammable sub-

stance, significantly increasing the safety of natural gas processing plants and transmission and distribution systems. This can be particularly important at offshore installations, where risks associated with hazardous and flammable materials are greater.

- ★ **Lower Methane Emissions.** Reductions in methane emissions have been reported as high as 70,000 Mcf per facility annually, depending on the device(s) and the type of control application.

Decision Process

The conversion of natural gas pneumatics to instrument air system is applicable to all natural gas facilities and plants. To determine the most cost-effective applications, however, requires a technical and economic feasibility study. The six steps outlined below, and the practical example with cost tables, equations, and factors, can help companies to evaluate their opportunities.

Decision Process for Converting Gas Pneumatic Devices to Instrument Air:

1. Identify possible locations for system installations.
2. Determine optimal system capacity.
3. Estimate the project costs.
4. Estimate gas savings.
5. Evaluate the economics.
6. Develop an implementation plan.

Step 1: Identify Possible Locations For Instrument Air System Installations. Most natural gas-operated pneumatic control systems can be replaced with instrument air. Instrument air systems will require new investments for the compressor, dehydrator, and other related equipment, as well as a supply of electricity. As a result, a first step in a successful instrument air conversion project is screening existing facilities to identify locations that are most suitable for cost effective projects. In general, three main factors should be considered during this process.

- ★ **Facility Layout.** The layout of a natural gas facility can significantly affect equipment and installation costs for an instrument air system. For example, conversion to instrument air might not be cost effective at decentralized facilities where tank batteries are remote or widely scattered. Instrument air is most appropriate when used at offshore platforms and onshore facilities where pneumatics are consolidated within a relatively small area.

- ★ **Number Of Pneumatics.** The more pneumatic controllers converted to instrument air, the greater the potential for reduced emissions and increased company savings. Conversion to instrument air is most profitable when a company is planning a facility-wide change.

- ★ **Available Power Supply.** Since most instrument air systems rely on electric power for operating the compressor, a cost-effective, uninterrupted electrical energy source is essential. While major facilities often have an existing power supply or their own power generation system, many smaller and remote facilities do not. For these facilities, the cost of power generation generally makes the use of instrument air unprofitable. In addition, facilities with dedicated generators need to assess whether the generators have enough available capacity to support an air compression system, as the cost of a generator upgrade can be prohibitive. Remote facilities should examine alternatives for power generation, which range from microturbines to solar power.

Step 2: Determine Optimal System Capacity. Once project sites have been identified, it is important to determine the appropriate capacity of the new instrument air system. The capacity needed is a direct function of the amount of compressed air needed to both operate the pneumatic instrumentation and meet any utility air requirements.

★ **Instrument Air Requirements.** The compressed air needs for the pneumatic system are equivalent to the volume of gas being used to run the existing instrumentation—adjusted for air losses during the drying process. The current volume of gas usage can be determined by a direct meter reading (if a meter has been installed). In non-metered systems, a conservative rule of thumb for sizing air systems is one cubic foot per minute (cfm) of instrument air for each control loop (consisting of a pneumatic controller and a control valve).

Rule-of-Thumb:

1 cfm air/control loop

The initial estimate of instrument air needs should then be adjusted to account for air losses during the drying process. Typically, the membrane filters in the air dryer consume about 17 percent of the air input. As a result, the estimated volume of instrument air usage is 83 percent of the total compressed air supply: i.e. divide estimated air usage by 83 percent. Desiccant dryers do not consume air and therefore require no adjustment.

Rule-of-Thumb:

17 percent of air input is consumed by the membrane dryer

★ **Utility Air Requirements.** It is common to use compressed air for utility purposes, such as engine starters, pneumatic driven pumps, pneumatic tools (e.g., impact wrenches), and sand blasting. Unlike instrument air, utility air does not have to be dried. The frequency and volumes of such utility air uses are additive. Companies will need to evaluate these other compressed air services on a site-specific basis, allowing for the possibility of expansion at the site. A general rule of thumb is to assume that the maximum rate of compressed air needed periodically for utility purposes will be double the steady rate used for instrument air.

Rule-of-Thumb:

Pneumatic air uses: 1/3 for instrument air; 2/3 for utility air

Exhibit 4 illustrates how the instrument air compressor size can be estimated. Using the rule of thumb of 1 cfm/control loop, the current gas usage would translate to approximately 35 cfm of dry instrument air. Adjusting for the dryer's air consumption (17 percent of air input), the total instrument air supply requirement will be 42 cfm. Factoring in utility air needs of about 70 cfm, the project would require a total of 112 cfm of compressed air.

Exhibit 4: Calculate Compressor Size for Converting Gas Pneumatics to Instrument Air	
Given:	For an average size production site with pneumatics, glycol dehydration, compression, 35 control loops, and an average of 10 cfm utility gas usage for pneumatic pumps and compressor engine starting.
A	= Total Compressed Air
IAu	= Instrument air use
IAs	= Instrument air supply
UAs	= Utility air supply
L	= Control Loops
	Rule-of-thumb: 1 cfm per control loop for estimating instrument air systems.
	Rule-of-thumb: 17% of air is bypassed in membrane dryers.
	Rule-of-thumb: 1/3 of total air used for instruments, 2/3 of total air used for utility services.
	Calculate: A = Air compressor capacity required.
A	= IAs + UAs
IAu	= L*(1 cfm/loop)
IAs	= IAu/(100% -% air bypassed in dryer)
UAs	= IAu*(fraction of utility air use) / (fraction of instrument air use)
A	= (35*1) / (100%-17%) + (35*1) * (2/3) / (1/3) = 112 cfm

Step 3: Estimate the Project Costs. The major costs associated with installing and operating an instrument air system are the installation costs for compressors, dryers, and volume tanks, and energy costs. The actual installation costs will be a function of the size, location, and other location specific factors. A typical conversion of a natural gas pneumatic control system to compressed instrument air costs approximately $35,000 to $60,000.

To estimate the cost for a given project, all expenses associated with the compressor, dryer, volume tank, and power supply must be calculated. Most vendors are willing to provide estimates of the equipment costs and installation requirements (including compressor size, motor horsepower, electrical power requirements, and storage capacity). Alternatively, operators can use the following information on the major system components to estimate the total installed cost of the instrument air system.

★ **Compressor Costs.** It is common to install two compressors at a facility (one operating and one stand-by spare) to ensure reliability and allow for maintenance and overhauls without service interruptions. The capacity for each of the compressors must be sufficient to handle the total expected compressed air volume for the project (i.e., both instrument and utility air). Exhibit 5 presents cost estimates for purchasing and servicing small, medium, and large compressors. For screw-type compressors, operators should expect to overhaul the unit every 5 to 6 years. This normally involves exchanging the compressor core for a rebuilt compressor at a cost of approximately $3,000, with an additional $500 in labor expense and a $500 core exchange credit.

Exhibit 5: Air Compressor Costs

Service Size	Air Volume (cfm)	Compressor Type	Horsepower	Equipment Costs ($)	Annual Service ($/yr)	Service Life (yrs)
Small	30	Reciprocating	10	2,500[1]	300	1
Medium	125	Screw	30	12,500	600	5-6[2]
Large	350	Screw	75	22,000	600	5-6[2]

[1] Cost included package compressor with a volume tank.
[2] Rebuilt compressor costs $3,000 plus $500 labor minus $500 core exchange credit.

★ **Volume Tank.** Compressed air supply systems include a volume tank, which maintains a steady pressure with the on-off operation of the air compressor. The rule-of-thumb in determining the size of the volume tank is 1-gallon capacity for each cfm of compressed air. Exhibit 6 presents equipment costs for small, medium, and large volume tanks. Volume tanks have essentially no operating and maintenance costs.

Rule-of-Thumb:

1 gallon tank capacity/1 cfm air

Exhibit 6: Volume Tank Costs

Service Size	Air Volume (gallons)	Equipment Cost ($)
Small[1]	80	500
Medium	400	1,500
Large	1,000	3,000

[1] Small reciprocating air compressors, 10 horsepower and less, are commonly supplied with a surge tank.

★ **Air Dryer Costs.** Because instrument air must be very dry to avoid plugging and corrosion, the compressed air is commonly put through a dryer. The most common dryer used in small to medium applications is a permeable membrane dryer. Larger air systems can use multiple membrane dryers, or, more cost effectively, alumina bed desiccant dryers. Membrane dryers filter out oil mist and particulate solids and have no moving parts. As a result, annual operating costs are kept low. Exhibit 7 presents equipment and service cost data for different size dryers. The appropriate sized dryer would need to accommodate the expected volume of gas needed for the instrument air system.

Exhibit 7: Air Dryer Costs

Service Size	Air Volume (cfm)	Dryer Type	Equipment Cost ($)	Annual Service ($/yr)
Small	30	membrane	1,500	500
Medium	60[1]	membrane	4,500	2,000
Large	350	alumina	10,000	3,000

[1] Largest membrane size; use multiple units larger volumes.

Using the equipment information described above, the total installed cost for a project can be calculated. Exhibit 8 illustrates this using the earlier example of a medium-sized production facility with an instrument air requirement of 42 cfm and a maximum utility air requirement of 70 cfm (for a total of 112 cfm of compressed air). To estimate the installed cost of equipment, it is a common practice in industry to assume that installation labor is equivalent to equipment purchase cost (i.e. double equipment purchase cost to estimate the installed cost). This would be suitable for large, desiccant dried instrument air systems, but for small, skid-mounted instrument air systems a factor of 1.5 is used to estimate the total installed cost (installation labor is half the cost of equipment).

Exhibit 8: Calculate Total Installation Costs

Given:		
	Compressors (2) Volume Tanks (2-small) Membrane Dryer Installed Cost Factor	= $25,000 (exhibit 5) = $1,000 (exhibit 6) = $4,500 (exhibit 7) = 1.5
Calculate Total Installed Cost:		
	Equipment Cost	= Compressor Cost + Tank Cost + Dryer Cost = $25,000 + $1,000 + $4,500 = $30,500
	Total Cost	= Equipment Cost * Installation Cost Factor = $30,500 * 1.5 = $45,750

In addition to the facility costs, it is also necessary to estimate the energy costs associated with operating the system. The most significant operating cost of an air compressor is electricity, unless the site has excess self-generation capacity. To continue the example from above, assuming that electricity is purchased at 7.5 cents per kilowatt-hour (kWh) and that one compressor is in standby while the other compressor runs at full capacity half the time (a 50 percent operating factor), the electrical power cost amounts to $13,140 per year. This calculation is shown in Exhibit 9.

Exhibit 9: Calculate Electricity Cost		
Given:		
	Engine Power Operating Factor (OF) Electricity Cost	= 30 HP = 50 percent = $0.075/kwh
Calculate Required Power:		
	Electrical Power	= Engine Power * OF * Electricity Cost = [30 HP * 8,760hrs/yr * 0.5 * $0.075/kwh] / 0.75 HP/kw = $13,140/yr

Step 4: Estimate Gas Savings. To estimate the gas savings that result from the installation of an instrument air system, it is important to determine the normal bleed rates (continuous leak from piping networks, control devices, etc.), as well as the peak bleed rates (associated with movements in the control devices). One approach is to list all the control devices, assess their normal and peak bleed rates, frequency of actuation, and estimates of leakage from the piping networks. Manufacturers of the control devices usually publish the emission rates for each type of device, and for each type of operation. Rates should be increased by 25 percent for devices that have been in service without overhaul for five to 10 years, and by about 50 percent for devices that have not been overhauled for more than 10 years to account for increased leakage associated with wear and tear. Alternatively, installing a meter can be more accurate, provided monitoring occurs over a long enough period of time to take account of all the utility uses of gas (i.e., pumps, motor starters, activation of isolation valves).

EPA's *Lessons Learned: Options for Reducing Methane Emissions from Pneumatic Devices in the Natural Gas Industry*, provides brand name, model, and gas consumption information for a wide variety of currently used pneumatic devices. Manufacturer information and actual field measurement data, wherever available, are provided as well (see Appendix of that report). To simplify the calculation of gas savings for the purpose of this lesson learned analysis, we can use the earlier rules-of-thumb to estimate the gas savings. The gas savings for the medium-sized production facility example in Exhibit 4 include the conservatively estimated 35 cfm used in the 35 gas pneumatic controllers plus the gas used occasionally for compressor motor starters and small pneumatic chemical and transfer pumps. (Note that replacing these gas usages will result in direct savings of gas emissions.) Natural gas is not used for pneumatic tools or sand blasting, so additional compressed air provided for these services does not reduce methane emissions. Assuming an annual average of 10 cfm gas use for natural gas powered non-instrument services, the gas savings would be 45 cfm. As shown in Exhibit 10, this is equivalent to 23,652 Mcf per year and annual savings of $71,000.

Exhibit 10: Calculate Gas Savings		
Given:		
	Pneumatic instrument gas usage	= 35 cfm
	Other non-instrument gas usage	= 10 cfm
Calculate Value of Gas Saved:		
	Volume of Natural Gas Saved	= Instrument Usage + Other Usage = 35 cfm + 10 cfm = 45 cfm
	Annual Volume of Gas Saved	= 45 cfm * 525,600 min/yr / 1000 = 23,652 Mcf/yr
	Annual Value of Gas Saved	= volume * $3.00/Mcf = 23,652 Mcf/yr * $3.00/Mcf = $71,000/year

Step 5: Evaluate the Economics. The cost effectiveness of replacing the natural gas pneumatic control systems with instrument air systems can be evaluated using straightforward cost-benefit economic analyses.

Exhibit 11 illustrates a cost-benefit analysis for the medium-sized production facility example. The cash flow over a five-year period is analyzed by showing the magnitude and timing of costs from Exhibits 8 and 9 (shown in parentheses) and benefits from Exhibit 10. The annual maintenance costs associated with the compressors and air dryer, from Exhibits 5 and 7, are accounted for, as well as a five-year major overhaul of a compressor per Exhibit 5. The net present value (NPV) is equal to the benefits minus the costs accrued over five years and discounted by 10 percent each year. The Internal Rate of Return (IRR) reflects the discount rate at which the NPV generated by the investment equals zero.

Exhibit 11: Economic Analysis of Instrument Air System Conversion

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
Installation Cost ($)	(45,750)					
O&M Cost ($)	0	(13,140)[1] (3,200)[2]	(13,140) (3,200)	(13,140) (3,200)	(13,140) (3,200)	(13,140) (3,200)
Overhaul Cost ($)	0	0	0	0	0	(4,800)[3]
Total Cost ($)	(45,750)	(16,340)	(16,340)	(16,340)	(16,340)	(21,140)
Gas Savings ($)	0	71,000[4]	71,000	71,000	71,000	71,000
Annual Cash Flow ($)	(45,750)	54,660	54,660	54,660	54,660	49,860
Cumulative Cash Flow($)	(45,750)	8,910	63,570	118,230	172,890	222,750
					Payback Period (months)	**10**
					IRR	**177%**
					NPV[5]	**$158,454**

[1] Electrical power at 7.5 cents per kilowatt-hour
[2] Maintenance costs include $1,200 compressor service and $2,000 air dryer membrane replacement
[3] Compressor overhaul cost of $3,000, inflated at 10% per year.
[4] Value of gas = $3.00/Mcf
[5] Net Present Value (NPV) based on 10% discount rate for 5 years.

Step 6: Develop an Implementation Plan. After determining the feasibility and economics of converting to an instrument air system, develop a systematic plan for implementing the required changes. This can include installing a gas measuring meter in the gas supply line, making an estimate of the number of control loops, ensuring an uninterrupted supply of electric energy for operating the compressors, and replacing old, obsolete and high-bleed controllers. It is recommended that all necessary changes be made at one time to minimize labor costs and disruption of operations. This might include a parallel strategy to install low-bleed devices in conjunction with the switch to instrument air systems. There are similar economic savings for conserving instrument air use as for conserving methane emissions with low bleed pneumatic devices. Whenever specific pneumatic devices are being replaced, such as in the case of alternative mechanical and/or electronic systems, the existing pneumatic devices should be replaced on a similar economic basis as discussed in the companion document *Lessons Learned: Options for Reducing Methane Emissions from Pneumatic Devices in the Natural Gas Industry*.

Partner Experiences

Several EPA Natural Gas Star partners have reported the conversion of natural gas pneumatic control systems to compressed instrument air systems as the single most significant source of methane emission reduction and a source of substantial cost savings. Exhibit 12 below highlights the accomplishments that several Natural Gas STAR partners have reported.

Exhibit 12: Partner Reported Experience

Gas STAR Partner	Description of Project	Project Cost ($)	Annual Emissions Reductions (Mcf/Year)	Annual Savings ($/Year)[1]	Payback (Months)[2]
Unocal	Installed an air compression system in its Fresh Water Bayou facility in southern Vermillion Parish, Louisiana	60,000	69,350	208,050	<4
Texaco[3]	Installed compressed air system to drive pneumatic devices in 10 South Louisiana facilities	40,000	23,000	69,000	7
Chevron[3]	Converted to pneumatic controllers to compressed air, including new installations	173,000 over 2 years	31,700	95,100	11
Exxon/Mobil[4]	Installed instrument air systems at 3 production satellites and 1 central tank battery at Postle CO_2 unit	55,000	19,163	57,489	12
Shell	Used instrument air operated devices on over 4,300 valves at off-shore platforms	Not available	532,800	1,598,400	Not available
Marathon	Installed 15 instrument air systems in New Mexico facilities	Not available	120 - 38,000 per facility	360 - 114,000	Not available

[1] Value of gas = $3.00/Mcf.
[2] Calculated based on partner-reported costs and gas savings.
[3] Data for this report were collected prior to the Chevron-Texaco merger in 2001.
[4] Data for this report were collected prior to the Exxon/Mobil merger in 1999.

Other Technologies

The majority of partners' experiences in substituting natural gas-powered pneumatic devices and control instrumentation with alternative controllers have involved the installation of compressed instrument air systems. Some additional alternatives to gas pneumatics implemented by partners are described below:

- ★ **Liquid Nitrogen.** In a system using liquid nitrogen, the volume tank, air compressor, and dryer are replaced with a cylinder containing cryogenic liquid nitrogen. A pressure regulator allows expansion of the nitrogen gas into the instrument and control-piping network at the desired pressure. Liquid nitrogen bottles are replaced periodically. Liquid nitrogen-operated devices require handling of cryogenic liquids, which can be expensive as well as a potential safety hazard. Large volume demands on a liquid nitrogen system require a vaporizer.
- ★ **Mechanical Controls and Instrumentation System.** Mechanical instrument and control devices have a long history of use in the natural gas and petroleum industry. They are usually distinguished by the absence of pneumatic and electric components, are simple in design, and require no power source. Such equipment operates using springs, levers, baffles, flow channels, and hand wheels. They have several disadvantages, such as limited application, the need for continuous calibration, lack of sensitivity, inability to handle large variations, and potential for sticking parts.
- ★ **Electric and Electro-Pneumatic Devices.** As a result of advanced technology and increasing sophistication, the use of electronic instrument and control devices is increasing. The advantage of these devices is that they require no compression devices to supply energy to operate the equipment; a simple 120-volt electric supply is used for power. Another advantage is that the use of electronic instrument and control devices is far less dangerous than using combustible natural gas or cryogenic liquid nitrogen cylinders. The disadvantage of these devices is their reliance on an uninterrupted source of electric supply, and significantly higher costs.

Although these options have advantages, systems using air instead of natural gas are the most widely employed alternative in replacing natural gas-operated pneumatic control devices. It is important to note that maintaining a constant, reliable supply of dry, compressed air in a plant environment is a significant cost, albeit more economic than natural gas. Therefore, a parallel strategy to install low-bleed devices in conjunction with the switch to instrument air systems (refer to *Lessons Learned: Options for Reducing Methane Emissions from Pneumatic Devices in the Natural Gas Industry*), and to design a maintenance schedule to keep the instruments and control devices in tune, is often economic. Such actions can significantly reduce the consumption of instrument air in the overall system and, therefore, minimize both the size of the compression system and the electricity consumption over the life of the plant.

Lessons Learned

The lessons learned from Natural Gas STAR partners are:

- ★ Installing instrument air systems has the potential to increase revenues and substantially reduce methane emissions.
- ★ Instrument air systems can extend the life cycle of system equipment, which can accumulate trace amounts of sulfur and various acid gases when controlled by natural gas, thus adding to the potential savings and increasing operational efficiencies.
- ★ Remote locations and facilities without a reliable source of electric supply often need to evaluate alternate power generation sources. When feasible, solar-powered air compressors provide an economical and ecologically beneficial alternative to expensive electricity in remote production areas. On site generation using microturbines running on natural gas is another alternative.
- ★ A parallel strategy of installing low-bleed devices in conjunction with the switch to instrument air systems is often economic.
- ★ Existing infrastructure can be used; therefore, no pipe replacement is needed. However, existing piping and tubing should be flushed clear of accumulated debris.
- ★ Rotary air compressors are normally lubricated with oil, which must be filtered to maintain the life and proper performance of membrane dryers.
- ★ Use of instrument air will eliminate safety hazards associated with flammable natural gas usage in pneumatic devices.
- ★ Nitrogen-drive systems may be an alternative to instrument air in special cases, but tends to be expensive and handling of cryogenic gas is a safety concern.
- ★ Report reductions in methane emissions from converting gas pneumatic controls to instrument air in your Natural Gas STAR Annual Report.

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